Studies of Air-Sea Coupling as Part of CBLAST High
2006 Annual Report

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LONG-TERM GOALS

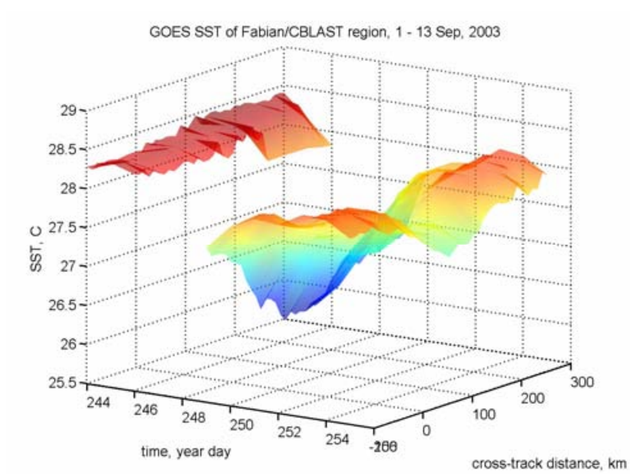
A question that came out of a study of satellite imagery from the hurricane Fabian data set was --- What process causes the cool SST in a hurricane wake to recover to pre-hurricane values? The recovery is quite rapid, in the Fabian case e-folding in five days, and so has a significant impact upon the inference of SST cooling using satellite data.

OBJECTIVES

The major effort during 2006 was directed to two air-sea modeling projects; Hurricane-Ocean Interaction with S. Chen, which I will mention toward the end, and analysis of SST relaxation of the cool wake of hurricane, a collaboration with J. Morzel and P. Niiler. This report will emphasize the latter project.

APPROACH

The method is first to document the SST cooling and recovery in observations -- the figure below has been derived from GOES IR imagery:



This three-dimensional surface depicts SST as the ‘up’ coordinate along a 400 km wide swath across the track of hurricane Fabian in the Sargasso Sea. The data at the left of the figure are pre-hurricane, and indicate SST that was rather warm and quasi-uniform, typical of the late summer subtropics.

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There is a gap of several days associated with the cloud cover of Fabian, and then a much cooler SST immediately afterwards. The SST warms and recovers back toward pre-hurricane conditions with an e-folding of about five days. Drifter SST (Morzel and Niiler) data have made a very useful check and supplement on this satellite data; the drifter data have a much smaller random error and high precision, and they also have much better temporal resolution than does the GOES IR imagery shown here.

WORK COMPLETED

There are many examples of the SST cooling and recovery associated with hurricane passage and I have analyzed six examples. Most are very similar to the Fabian case shown above. Interestingly, the exception is the 2004 CBLAST hurricane Frances case, in which the e-folding is closer to two weeks.

RESULTS

The hypothesis being developed and tested here has two parts 1) that the SST recovery is a local process driven in part by an anomalous (compared to the regions outside the cool wake) air-sea heat flux. The heat flux over the cool wake region is biased positive, typically by about 40 W/m^2 simply because the SST is cooler than surrounding regions (or the nominal late summer conditions). This is a rather direct inference from the data. The subtle question is – How can such a small heat flux produce such a rapid warming rate? The second part of the hypothesis is that 2) the evident shallow trapping depth of this anomalous heat flux is determined not by the anomalous heat flux itself (it is much too small) but rather by the large amplitude diurnal cycle that accompanies fair weather conditions following most (though not all) hurricanes.

This two part hypothesis, combined with a model of the diurnal cycle, leads to leads to simple solution for the e-folding time of the SST recovery, $\Gamma \sim \tau/\Lambda \mathrm{sqrt}(Qnoon)$, where Λ is known from air-sea transfer formula and is proportional to the anomalous heat flux, and Qnoon is the amplitude of the diurnal maximum of the air-sea heat flux (note that the theory leads to a closed solution including thermodynamic constants omitted here). The wind stress has been evaluated from QuikScat data and is a regional and time average.

This solution compares very well with the Fabian example, giving an e-folding of about five days, and it shows why the Frances case was somewhat different – post Frances the weather remained somewhat disturbed, cloudy and windy, and hence the SST recovery was delayed.
Much more detail on this project is available from a PowerPoint file of a talk delivered to the 2006 AMS Hurricane Conference, see http://www.whoi.edu/science/PO/people/jprice/PWP/JPrice_AMS_2006.ppt

SCIENTIFIC IMPACT AND APPLICATIONS

Two notable conclusions of this analysis are that: 1) The response of SST in strong heating conditions depends only upon the surface fluxes, while under cooling or wind mixing conditions, e.g., the forced stage response, SST will depend also upon the initial stratification of the upper ocean. 2) The e-folding time for warming depends upon both the slowly varying heat flux, $\sim\Lambda$, which determines the sign of the SST trend, and a measure of the *variance* of the heat flux, Qnoon, which contributes significantly to setting the amplitude of the SST warming. This dependence upon the variance of the surface heat flux is expected to hold generally under conditions of strong heating, but not under conditions of sustained cooling or strong wind mixing.

This study gives explicit evidence that the ocean's SST response to heating and cooling is quite asymmetric. Climatological air-sea heat flux data will suffice for modeling cooling or wind-mixing conditions, but air-sea fluxes that resolve the diurnal cycle of solar insolation will be required, in principal, for strong heating conditions.

RELATED PROJECTS

Other related projects from CBLAST are ongoing and coming to fruition. 1) I have also been working with Prof. Shuyi Chen of RSMAS U. of Miami to provide an ocean model that is suitable for the purpose of simulating air-sea interaction in hurricane conditions. Chen and her PhD students have used this model variant of Price et al. (1994), dubbed 3DPWP, with some success and a brief report of that work is in Chen et al., (2006).

To help build the bridge between the rather specialized/idealized 3DPWP ocean model and a comprehensive OGCM that will be needed in the long-term, I have started a model intercomparison project built around CBLAST data, see the web site: http://www.whoi.edu/sbl/liteSite.do?litesiteid=8232&articleId=12187

REFERENCES AND PUBLICATIONS

Chen, S., J. F. Price, W. Zhao, M. Donelan, E. J. Walsh, 2006. The CBLAST-Hurricane Program and the Next-Generation Fully Coupled Atmosphere-Wave-Ocean Models for Hurricane Research and Prediction, to appear, Bull. Am. Met. Soc.

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